

1. A process for recovery of hexavalent chromium from a stream comprising:

providing the stream containing hexavalent chromium;

reacting a soluble non-toxic precipitating reagent with the hexavalent chromium to form an insoluble precipitating reagent-chromate precipitate;

5 reacting the insoluble precipitating reagent-chromate precipitate with an acidic solution to form an insoluble precipitating reagent precipitate and a soluble hexavalent chromium compound; and

recovering the soluble hexavalent chromium compound.

10 2. The process of claim 1 wherein the soluble non-toxic precipitating reagent is selected from bismuth compounds; lanthanide compounds; aluminum compounds; titanium compounds, trivalent chromium compounds; organic compounds containing a group selected from nitronium, phosphonium, sulfonium, stibonium, iodonium, pyrylium, or combinations thereof; or combinations thereof.

15 3. The process of claim 1 wherein the acidic solution is selected from sulfuric acid, hydrochloric acid, hydrofluoric acid, boric acid, phosphoric acid, pyrophosphoric acid, phosphomolybdic acid, phosphotungstic acid, silicomolybdic acid, silicotungstic acid, or combinations thereof.

20 4. The process of claim 1 wherein the acidic solution is selected from acidic oxalates, malonates, succinates, maleates, fumarates, malates, tartrates, salicylates, or combinations thereof.

5. The process of claim 1 wherein the insoluble precipitating reagent-chromate precipitate has a solubility of less than 1×10^{-2} M Cr^{+6} .

6. The process of claim 5 wherein the insoluble precipitating reagent-chromate precipitate has a solubility of less than 5×10^{-3} M Cr^{+6} .

7. The process of claim 1 wherein the process is carried out at temperatures in the range of from about 5°C to about 100°C .

8. The process of claim 1 wherein recovering the soluble hexavalent chromium compound comprises obtaining a solid using a process selected from evaporation, freeze drying, or salting out.

9. The process of claim 1 further comprising reacting the insoluble precipitating reagent precipitate with a solubilizing reagent to form the soluble non-toxic precipitating reagent.

10. The process of claim 9 wherein the solubilizing reagent is selected from nitric acid, perchloric acid, sulfuric acid, hydrochloric acid, acetic acid, propionic acid, lactic acid, citric acid, or combinations thereof.

11. The process of claim 9 further comprising recovering the soluble non-toxic precipitating reagent using a process selected from evaporation, freeze-drying, or salting out.

12. The process of claim 1 wherein the non-toxic precipitating reagent is an organic compounds} containing a group selected from nitronium or phosphonium.

13. A process for recovery of hexavalent chromium from a stream comprising:

- 5 providing the stream containing hexavalent chromium;
 reacting a soluble non-toxic precipitating reagent with the hexavalent chromium
to form an insoluble precipitating reagent-chromate precipitate; and
 recovering the insoluble precipitating reagent-chromate precipitate.

10 14. The process of claim 13 wherein the soluble non-toxic precipitating reagent is
selected from bismuth compounds; lanthanide compounds; aluminum compounds;
titanium compounds, trivalent chromium compounds; organic compounds containing a
group selected from nitronium, phosphonium, sulfonium, stibonium, iodonium, pyrylium,
or combinations thereof; or combinations thereof.

15 15. The process of claim 13 wherein the insoluble precipitating reagent-chromate
precipitate has a solubility of less than $1 \times 10^{-2} \text{ M Cr}^{+6}$.

20 16. The process of claim 15 wherein the insoluble precipitating reagent-chromate
precipitate has a solubility of less than $5 \times 10^{-3} \text{ M Cr}^{+6}$.

17. The process of claim 13 wherein the process is carried out at temperatures in the
range of from about 5°C to about 100°C.

18. The process of claim 17 further comprising:

reacting the insoluble precipitating reagent-chromate precipitate with an acidic solution to form an insoluble precipitating reagent precipitate and a soluble hexavalent chromium compound; and

5 recovering the soluble hexavalent chromium compound.

19. The process of claim 18 wherein the acidic solution is selected from sulfuric acid, hydrochloric acid, hydrofluoric acid, boric acid, phosphoric acid, pyrophosphoric acid, phosphomolybdic acid, phosphotungstic acid, silicomolybdic acid, silicotungstic acid, or combinations thereof.

20. The process of claim 18 wherein the acidic solution is selected from acidic oxalates, malonates, succinates, maleates, fumarates, malates, tartrates, salicylates, or combinations thereof.

21. The process of claim 18 wherein recovering the soluble hexavalent chromium compound comprises obtaining a solid using a process selected from evaporation, freeze drying, or salting out.

20 22. The process of claim 1 further comprising reacting the insoluble precipitating reagent precipitate with a solubilizing reagent to form the soluble non-toxic precipitating reagent.

same as
cl. 9.

23. The process of claim 22 wherein the solubilizing reagent is selected from nitric acid, perchloric acid, sulfuric acid, hydrochloric acid, acetic acid, propionic acid, lactic acid, citric acid, or combinations thereof.

Same as
cl. 10.

5 24. The process of claim 22 further comprising recovering the soluble non-toxic precipitating reagent using a process selected from evaporation, freeze-drying, or salting out.

Same as
cl. 11

10 25. The process of claim 13 wherein the non-toxic precipitating reagent is an organic compounds having a group selected from nitronium or phosphonium.

26. A process for recovery of hexavalent chromium from a stream comprising:

providing the stream containing hexavalent chromium;

reacting a soluble non-toxic precipitating reagent with the hexavalent chromium

15 to form an insoluble precipitating reagent-chromate precipitate, the soluble non-toxic precipitating reagent selected from bismuth compounds; lanthanide compounds; aluminum compounds; titanium compounds, trivalent chromium compounds; organic compounds containing a group selected from nitronium, phosphonium, sulfonium, stibonium, iodonium, pyrylium, or combinations thereof; or combinations thereof;

20 reacting the insoluble precipitating reagent-chromate precipitate with an acidic solution to form an insoluble precipitating reagent precipitate and a soluble hexavalent chromium compound;

recovering the soluble hexavalent chromium compound; and

reacting the insoluble precipitating reagent precipitate with a solubilizing reagent to form the soluble non-toxic precipitating reagent.

27. The process of claim 26 wherein the acidic solution is selected from sulfuric acid, hydrochloric acid, hydrofluoric acid, boric acid, phosphoric acid, pyrophosphoric acid, phosphomolybdic acid, phosphotungstic acid, silicomolybdic acid, silicotungstic acid, or combinations thereof.

28. The process of claim 26 wherein the acidic solution is selected from acidic oxalates, malonates, succinates, maleates, fumarates, malates, tartrates, salicylates, or combinations thereof.

29. The process of claim 26 wherein the insoluble precipitating reagent-chromate precipitate has a solubility of less than 1×10^{-2} M Cr^{+6} .

30. The process of claim 29 wherein the insoluble precipitating reagent-chromate precipitate has a solubility of less than 5×10^{-3} M Cr^{+6} .

31. The process of claim 26 wherein the solubilizing reagent is selected from nitric acid, perchloric acid, sulfuric acid, hydrochloric acid, acetic acid, propionic acid, lactic acid, citric acid, or combinations thereof.

32. The process of claim 26 wherein the process is carried out at temperatures in the range of from about 5°C to about 100°C.

33. The process of claim 26 wherein recovering the soluble hexavalent chromium compound comprises obtaining a solid using a process selected from evaporation, freeze drying, or salting out.

34. The process of claim 26 further comprising recovering the soluble non-toxic precipitating reagent using a process selected from evaporation, freeze-drying, or salting out.

35. The process of claim 26 wherein the non-toxic precipitating reagent is an organic compound having a group selected from nitronium or phosphonium.

36. The method of claim 9 further comprising heating the insoluble precipitating reagent precipitate to a temperature of less than about 250°C to convert the insoluble precipitating reagent precipitate to an oxide or hydroxide before reacting the insoluble precipitating reagent precipitate with the solubilizing reagent.

37. The method of claim 22 further comprising heating the insoluble precipitating reagent precipitate to a temperature of less than about 250°C to convert the insoluble precipitating reagent precipitate to an oxide or hydroxide before reacting the insoluble precipitating reagent precipitate with the solubilizing reagent.

38. The method of claim 26 further comprising heating the insoluble precipitating reagent precipitate to a temperature of less than about 250°C to convert the insoluble precipitating reagent precipitate to an oxide or hydroxide before reacting the insoluble precipitating reagent precipitate with the solubilizing reagent.

5

39. The method of claim 1 wherein the stream containing hexavalent chromium is selected from chrome plating process waste streams, anodizing process waste streams, conversion coating process waste streams, phosphating process waste streams, paint process waste streams, paint extract process waste streams, polymerization process waste streams, leather tanning process waste streams, wood preservative waste streams, fungicide waste streams, pesticide waste streams, landfill waste streams, contaminated site waste streams, or combinations thereof.

10

40. The method of claim 13 wherein the stream containing hexavalent chromium is selected from chrome plating process waste streams, anodizing process waste streams, conversion coating process waste streams, phosphating process waste streams, paint process waste streams, paint extract process waste streams, polymerization process waste streams, leather tanning process waste streams, wood preservative waste streams, fungicide waste streams, pesticide waste streams, landfill waste streams, contaminated site waste streams, or combinations thereof.

20

41. The method of claim 26 wherein the stream containing hexavalent chromium is selected from chrome plating process waste streams, anodizing process waste streams,

conversion coating process waste streams, phosphating process waste streams, paint
process waste streams, paint extract process waste streams, polymerization process waste
streams, leather tanning process waste streams, wood preservative waste streams,
fungicide waste streams, pesticide waste streams, landfill waste streams, contaminated
5 site waste streams, or combinations thereof.

42. The method of claim 1 wherein the stream containing hexavalent chromium is an
aqueous stream.

10 43. The method of claim 13 wherein the stream containing hexavalent chromium is an
aqueous stream.

44. The method of claim 26 wherein the stream containing hexavalent chromium is an
aqueous stream.

1006533-013102
20150701 15:59:00